INCOMPLETE BONE RECOVERY AT THE DISTAL TIBIA IN ASTRONAUTS WITH ELEVATED MARKERS OF BONE TURNOVER

Leigh Gabel[1], Anna-Maria Liphardt[2], Martina Heer[3], Sara R. Zwart[4], Jean D. Sibonga[5], Scott M. Smith[5], Steven K. Boyd[1]
[1]University of Calgary, Calgary, AB Canada, [2] Friedrich-Alexander-University Erlangen-Nürnberg and Universitätsklinikum Erlangen, Erlangen, Germany, [3]University of Bonn, Bonn, Germany, [4]University of Texas Medical Branch, Galveston, TX, [5]NASA Lyndon B. Johnson Space Center, Houston, USA
leigh.gabel@ucalgary.ca

INTRODUCTION

Determining whether bone recovers after prolonged spaceflight is important for understanding the risks to astronaut long-term skeletal health and the limits of bone adaptation. The primary aim of this study was to use second-generation HR-pQCT to examine recovery of bone microarchitecture, density, and strength after long-duration spaceflight. Secondary aims included examining the effect of mission duration and biochemical measures of bone turnover on bone recovery.

METHODS

We examined bone strength, density, and microarchitecture before and after spaceflight and during 12 months of recovery in seventeen astronauts (3 women, 14 men; mean age 47 years). Distal tibiae were imaged 4 times (before flight, at return and at 6- and 12-months after return) using high-resolution peripheral quantitative computed tomography (HR-pQCT; XtremeCT II; 61μm). Post-flight bone images were 3D-registered to baseline images. Finite element analysis was applied to estimate bone strength. Blood and urine biochemical markers of bone turnover were acquired before, during, at return and at 6- and 12-months after return. Mixed effects models examined changes in bone and biochemical variables across time and the relationship between changes in bone variables and mission duration. Bone was considered recovered if total bone mineral density (BMD) recovered to within the least significant change by 12-month follow-up.

RESULTS

Mean mission duration was 170 days, with eight astronauts on missions longer than 6-months duration (mean 6.5 months) and nine astronauts on missions less than 6-months duration (mean 4.9 months). After 12 months of recovery, group median tibia bone strength (F.Load), total, cortical, and trabecular bone mineral density (BMD), trabecular bone volume fraction, and trabecular thickness remained -0·9% to -2·1% reduced compared with pre-flight ($p<0.001$). Astronauts on longer missions had poorer bone recovery compared with astronauts on shorter missions. For example, F.Load recovered by 12-months post-flight in astronauts on shorter (-0·4% median deficit) but not longer (-3·9%) missions. Compared with pre-flight, F.Load was -334 N (95% CI -497.5 to -170.2) in astronauts on longer missions and -80 N (95% CI -227 to 68) in astronauts on shorter missions after 12 months of recovery. Similar disparities were noted for total, trabecular, and cortical BMD, and trabecular separation. Altogether, nine of 17 astronauts did not recover tibia total BMD after 12-months recovery, including all eight astronauts on missions longer than 6-months duration. Astronauts with incomplete bone recovery had elevated biomarkers of bone turnover before, during, and after spaceflight compared with astronauts who recovered. Specifically, C-telopeptide (CTx), N-telopeptide (NTx), and osteocalcin were higher, while sclerostin was lower, at all times in astronauts whose bone did not recover compared with astronauts who recovered ($p<0.05$).

DISCUSSION

One year after returning from long-duration spaceflight, most astronauts demonstrated incomplete recovery of bone density, strength, and trabecular thickness at the weight-bearing distal tibia. Incomplete recovery of bone density and strength was more pronounced in astronauts who flew on longer duration missions. Longer duration fliers also demonstrated substantially greater bone loss after spaceflight compared with astronauts on shorter missions. Identifying relationships between biomarkers of bone turnover and skeletal recovery provides insight into optimizing strategies to mitigate loss and enhance recovery of the skeleton. Astronauts whose bone did not recover had greater bone turnover at all time points compared with astronauts who recovered. Thus, pre-flight measures of bone resorption and formation may identify astronauts at greatest risk of bone loss at weight-bearing sites who would most benefit from additional countermeasures, be it enhanced exercise or a pharmaceutical intervention.